Recommended Guidelines for Sampling Soft-Bottom Demersal Fishes by Beach Seine and Trawl in Puget Sound

For

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LIST OF ACRONYMS

NODC	National Oceanographic Data Center
PSEP	Puuet Sound Estuary Program
PSWQA	Puget Sound Water Quality Authority
QA/QC	quality assurance/quality control

ACKNOWLEDGMENTS

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The primary authors of this chapter were Drs. Bruce Miller, Donald Gunderson, Paul Dinnel, Robert Donnelly, and David Armstrong of the School of Fisheries, (University of Washington) and Dr. Stephen Brown of Tetra Tech, Inc. Mr. Charles Eaton of Bio-Marine Enterprises provided technical review and the information contained in Appendix C.

INTRODUCTION

This document recommends methods for sampling subtidal, soft-bottom demersal fish assemblages in Puget Sound, Washington using beach seines and trawls. The methods described in this report are based on the results of a workshop (16 August 1988) and written reviews by representatives from most of the organizations that fund or conduct studies of demersal fishes in the Puget Sound region (Table 1).

The purpose for developing recommended protocols is to encourage all Puget Sound investigators conducting monitoring programs, baseline surveys, and intensive investigations to use standardized methods whenever possible. If this goal is achieved, then most data collected in Puget Sound should be directly comparable and usable in an integrated, sound-wide database. Such a database is necessary for developing and maintaining a comprehensive water quality management program for Puget Sound.

This document provides recommendations for equipment and procedures used for beach seining and trawling. Examples of pertinent studies are provided to illustrate a range of study designs and the kinds of conclusions that can be made from the resulting data sets. Each piece of recommended equipment is described in detail. Information is provided on use and limitations of the recommended equipment as well as on deployment and retrieval. Information is also provided on catch processing and data collection in the field and laboratory, quality assurance/quality control (QA/QC), and data reporting requirements. In developing the protocols, it was recognized that the methods used in studies of demersal fishes are continuously changing. The loose-leaf format of this document will allow modification of the recommended protocols in the future, if necessary, and the inclusion of additional protocols.

Although the following protocols are recommended for most studies conducted in Puget Sound, departures from these methods may be necessary to meet the special needs of individual projects. If departures are made, however, the funding agency or investigator should be aware that the resulting data may not be comparable with most other data of that kind.

TABLE 1. CONTRIBUTORS TO THE BEACH SEINE AND TRAWL PROTOCOLS

Name	Affiliation
David Armstrong[a,b]	University of Washington
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USE AND LIMITATIONS

The equipment discussed in this document is commonly used in research and monitoring studies related to soft-bottom demersal fishes in Puget Sound. The assemblages considered in this document consist of demersal fish species that inhabit soft-bottom substrates (e.g., mud, sand, gravel, small cobble). These assemblages are classified by habitat in Figure 1.

The recommended equipment and methods are frequently used to identify spatial and temporal changes in the demersal fish assemblages of Puget Sound and to evaluate possible causes of any observed changes. Possible causes of observed changes in these assemblages include natural phenomena (e.g., variable recruitment due to changes in climate) pollution, and habitat degradation. Assemblage characteristics that can be determined using data generated according to these protocols include species diversity, relative abundance, reproductive condition, fish health, and the occurrence of various life history stages in different soft-bottom habitats.

These protocols are not intended for use in estimating the population characteristics needed to manage a commercial fishery, although the data generated using these protocols may be of supplementary value for this purpose. The protocols are also not intended for use in evaluating pelagic and tidepool species, or species that inhabit rocky substrates.

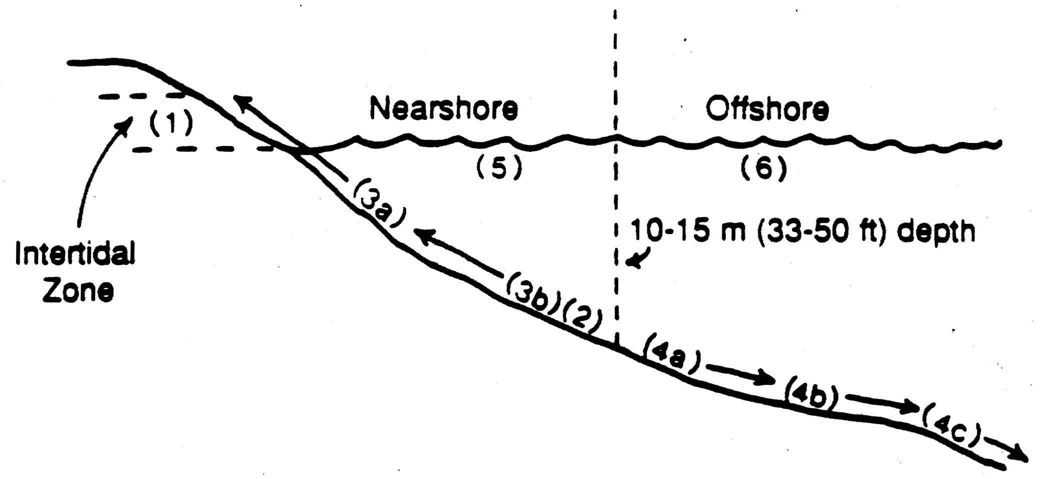
Most studies of demersal fishes in Puget Sound are concerned with the following issues:

- Effects of historical and ongoing point and nonpoint pollution (e.g., sewage and industrial discharges)

- Spatial and temporal patterns of abundance and habitat use of different life history stages, particularly in sites under consideration for development or alteration (e.g., by dredging, dredged material disposal, or effluent discharge).

EXAMPLES OF RECENT STUDIES OF DEMERSAL FISHES

Three recent studies of demersal fishes in Puget Sound are discussed below. Workshop participants suggested that examples be provided to illustrate the kinds of studies that are commonly conducted, the kinds of sampling equipment that are frequently used, and the kinds of conclusions that can be drawn from such studies.



HABITAT ASSEMBLAGE

(1) Intertidal rock-cobble fish assemblage

(2) Nearshore rocky reef assemblage

(3) Nearshore soft-bottom fish assemblages
- (3a) Intertidal to 5 m (0-16 ft) depth
- (3b) 5-10 m (16-33 ft) depth

(4) Offshore soft-bottom fish assemblage
- (4a) 10-30 m (33-100 ft) depth
- (4b) 30-70 m (100-230 ft) depth
- (4c) >70 m (>230 ft) depth

(5) Nearshore pelagic fish assemblage

(6) Offshore pelagic fish assemblage

Reference: Wingert and Miller (1979); Miller (1988).

Figure 1. Puget Sound marine habitats and fish assemblages.

Epizootiology of Skin Tumors of Juvenile English Sole

The prevalence of skin tumors in juvenile English sole was studied in the vicinity of Seattle, Washington by Angell et al. (1975). Collections were obtained during 1969 and 1970, and additional data from 1966 and 1967 were also available. Small (i.e., young) specimens were collected in shallow water using a beach seine. Monthly collections were made at low tide over a 1-year period. Three to six replicate hauls were made on a given sampling date. A small otter trawl was used at subtidal sites to collect larger juvenile and subadult specimens. Monthly samples were collected from November through June. Three to eight hauls were made at depth contours ranging from 3 to 30-m depth. Haul duration was 15 min, and haul speed was 75 m/min. Results of this study indicated that 1) tumor occurrence increased from August to October and declined thereafter, 2) both sexes were equally prone to having tumors, and 3) fish with tumors suffered higher mortality rates than individuals without tumors.

Puget Sound Baseline Study Program: Nearshore Fish Survey

Miller et al. (1977) conducted a study of nearshore fish assemblages in northern Puget Sound, to evaluate the potential for assemblage alterations that could result from the introduction of oil and other pollutants. Study areas were located in a region subject to oil pollution from refineries (i.e., near Anacortes, Washington) and in a reference region essentially free from oil pollution (i.e., western San Juan Islands). Several sampling devices were used because a range of habitats and life history stages were of interest.

Beach seines (37 m in length) were used to collect monthly samples of nearshore demersal fishes over two years. The beach seines were used in nearshore areas in cobble, gravel, sand/eelgrass, and mud/eelgrass habitats. Buoyant nets were used to sample the surface waters, and sinking nets were used to sample bottom waters. The results were used to characterize the distribution and dynamics of nearshore demersal fish assemblages at the study sites.

According to Miller et al. (1977), differences between the assemblages near the refinery and in the reference area were interpreted as being due to differences in habitat characteristics rather than pollutants. The nearshore demersal fish data, along with numerous data on other biological resources, were subsequently used for environmental assessments and evaluations of future projects.

Puget Sound Dredged Disposal Analysis

Demersal fish assemblages were surveyed in four sites in Puget Sound during 1986 and 1987 by Donnelly et al. (1986, 1988). The purpose of these studies was to evaluate the suitability of these sites for unconfined, open-water disposal of dredged material. During 1986, three sites were sampled one or two times during the summer and one site was sampled during February, April, June/July, and September. During 1987, three sites were sampled quarterly and an additional four sites were sampled twice (spring and fall). Samples were primarily collected using a 7.6-m otter trawl. One to three replicates were collected on each cruise. The sites were ranked on the basis of relative species abundance, species diversity, and species biomass. Information was also obtained on spatial distributions at the sites and seasonal changes in species abundance.

STUDY DESIGN CONSIDERATIONS

The designs of studies of demersal fish assemblages can vary substantially, depending upon study-specific objectives. Therefore, it is not possible to standardize all the elements that constitute a study design. Information is presented in this chapter concerning the technical issues that must be addressed when the study design is being developed. Additional information can be found in Wathne (1977), Mearns and Allen (1978), Byrne et al. (1981), and Pitt et al. (1981).

Development of an effective study design can be enhanced if decisions are based on actual information concerning the study area and the target species. Prior to determination of the final study design, a preliminary survey or reconnaissance cruise should be conducted in study areas for which the historical database is judged inadequate. Because of the differences that exist in the patterns of distribution, abundance, and life histories of fishes in Puget Sound, advice from individuals familiar with the fishes of Puget Sound should be sought when study designs are being developed. Advice may be obtained from scientists at the University of Washington, the Washington Department of Fisheries, and the National Marine Fisheries Service.

The following study design issues are discussed below:

- Project objectives
- Sampling schedule
- Habitat coverage
- Replication.

PROJECT OBJECTIVES

Project objectives must be defined before target species or assemblages, life history stages, and appropriate sampling equipment can be determined. A thorough assessment of ecological processes or potential environmental impacts would typically require a detailed analysis of entire assemblages of demersal fishes. A study in which all captured fish are analyzed can provide the most complete understanding of local diversity and habitat use, as well as provide the most comprehensive basis for assessing long-term trends. However, such studies will be more costly and time-consuming per station than a study in which only a limited number of species are considered. Thus, studies with limited objectives (e.g., monitoring the prevalence of liver lesions in English sole) can be conducted more efficiently if nontarget species are not analyzed in detail.

More than one sampling device may be needed in studies of multiple species, assemblages, or life history stages. For example, juvenile English sole are typically sampled using a 37-m beach seine, whereas subadult English sole are typically sampled using a 7.6-m otter trawl. However, because the samples of the different life history stages are not obtained using the same equipment, the samples are not directly comparable.

SAMPLING SCHEDULE

The frequency of sampling is determined by study-specific objectives. Information about the natural history of the target species is needed to estimate the time scales of interest. The monitoring of environmental impacts that occur over short time scales requires frequent sampling. For example, weekly sampling could be required to monitor impacts of dredging in nearshore sites when juvenile English sole are settling out of the water column. Monthly, or at least seasonal, sampling is usually required to follow the major life history events of a single target species. Moreover, a particular life history event may occur at different times for different species. For example, spawning occurs during the winter for Pacific cod and during the spring for herring. Also, juvenile English sole occur as two distinct cohorts during the winter and summer (Hart 1973).

Fish behavior can also influence sampling schedules. The depth and spatial distribu tions of many species change seasonally and over the 24-h light/dark cycle. Many demersal fishes occupy bottom habitats during the day and mid-water habitats during the night (Parsons and Parsons 1976; Pitt et al. 1981). Because the sampling equipment recommended in these protocols is designed to catch demersal fishes in bottom habitats, all routine monitoring of these fishes should be conducted during daylight hours. Daylight sampling has also been adopted by the National Marine Fisheries Service Resource Assessment and Conservation Engineering Division for programs monitoring demersal fishes along the outer Pacific coast.

HABITAT COVERAGE

A study area may contain more than one kind of habitat. In this situation, a stratified sampling design should be developed that includes sampling within each habitat type. Environmental characteristics that determine habitat types include sediment composition, vegetation, depth, salinity, and temperature. Different equipment may be required to sample in different habitat types. For example, a beach seine should be used to sample nearshore, shallow, eelgrass beds where juvenile stages frequently occur, whereas a 7.6-m otter trawl or a 400-mesh eastern otter trawl should be used to sample deeper areas where subadults and adults usually occur.

REPLICATION

The number of replicate tows that should be collected per station is influenced by both project objectives and practical considerations. Some projects may require collection of a given number of specimens, so that the actual numbers caught at a station will determine the number of tows required. For example, this situation may occur in studies of liver lesion prevalence in English sole. To obtain a particular level of statistical confidence, the required number of specimens is determined by lesion prevalence and population size (PSEP 1987). It is possible that the required sample could be collected in a single haul.

Because of variability in the abundances of demersal fishes and in the efficiencies of seines and trawls, studies involving detailed analyses of demersal fish assemblages (e.g., species composition, age structure) may require a substantial number of replicate tows per station. It is recommended that early in the process of developing a study design, investigators discuss study objectives with a statistician who is familiar with environmental studies. The determination of the required number of replicates may involve statistical power analysis using existing data. If no data are available, a preliminary survey can be conducted to obtain data for use in power analysis prior to completion of the final study design.

It may be prohibitively expensive to collect enough replicate tows to obtain a desired level of statistical power. In this situation, it may be necessary to accept a lower level of statistical power or revise the study objectives. In general, workshop participants recommended that a minimum of two or three replicate tows be collected per station on each sampling trip. More replicates will provide greater statistical power to detect patterns, but will also require a greater level of effort and cost. Most statistical tests commonly used to analyze environmental data (e.g., analysis of variance) require replication.

The locations of replicate tows should be allocated randomly within each habitat type. However, every effort should be made to ensure that replicate tows do not overlap spatially on a given sampling trip. Disturbance or removal of fishes caused by an initial tow can influence the catch of subsequent tows over the same area (Mearns and Allen 1978).

RECOMMENDED EQUIPMENT

STANDARD EQUIPMENT

The following equipment is recommended for use as the standard sampling gear for studies of soft-bottom demersal fish assemblages in Puget Sound:

- 37-m beach seine
- 7.6-m otter trawl
- 400-mesh eastern otter trawl.

All near-bottom life history stages of demersal fishes can be collected using these sampling devices. Moreover, these devices have been used extensively in historical studies of demersal fish assemblages in Puget Sound (Appendix A).

Descriptions of the 37-m beach seine, 7.6-m otter trawl, and 400-mesh eastern otter trawl are provided below. Net plans are provided in Appendix B.

37-m Beach Seine

The 37-m sinking beach seine (Figure 2) is 36.6 m in total length, with 18-m wing lengths. The net is constructed of 29-mm stretch mesh. The dimensions of the bag are 0.6 x 2.4 x 2.3 m, and the bag is lined with 6-mm stretch mesh (sometimes termed knotless netting). The center of the net is 2.4-m high, and the ends of the net are 0.9-m high. The ends of the net are attached to poles that are slightly longer than the 0.9-m net height. A pull or haul line is attached to each pole by means of a small bridle. The haul lines are typically made of nylon or soft polypropylene and are marked at 10-m intervals. A float line with small styrofoam floats runs along the top of the net. A solid-core lead line runs along the bottom of the net. Together, the buoyant float line and the sinking lead line cause the net to open vertically when it is in the water. By changing the buoyancy of the float line, the 37-m beach seine can be used to sample surface or bottom waters.

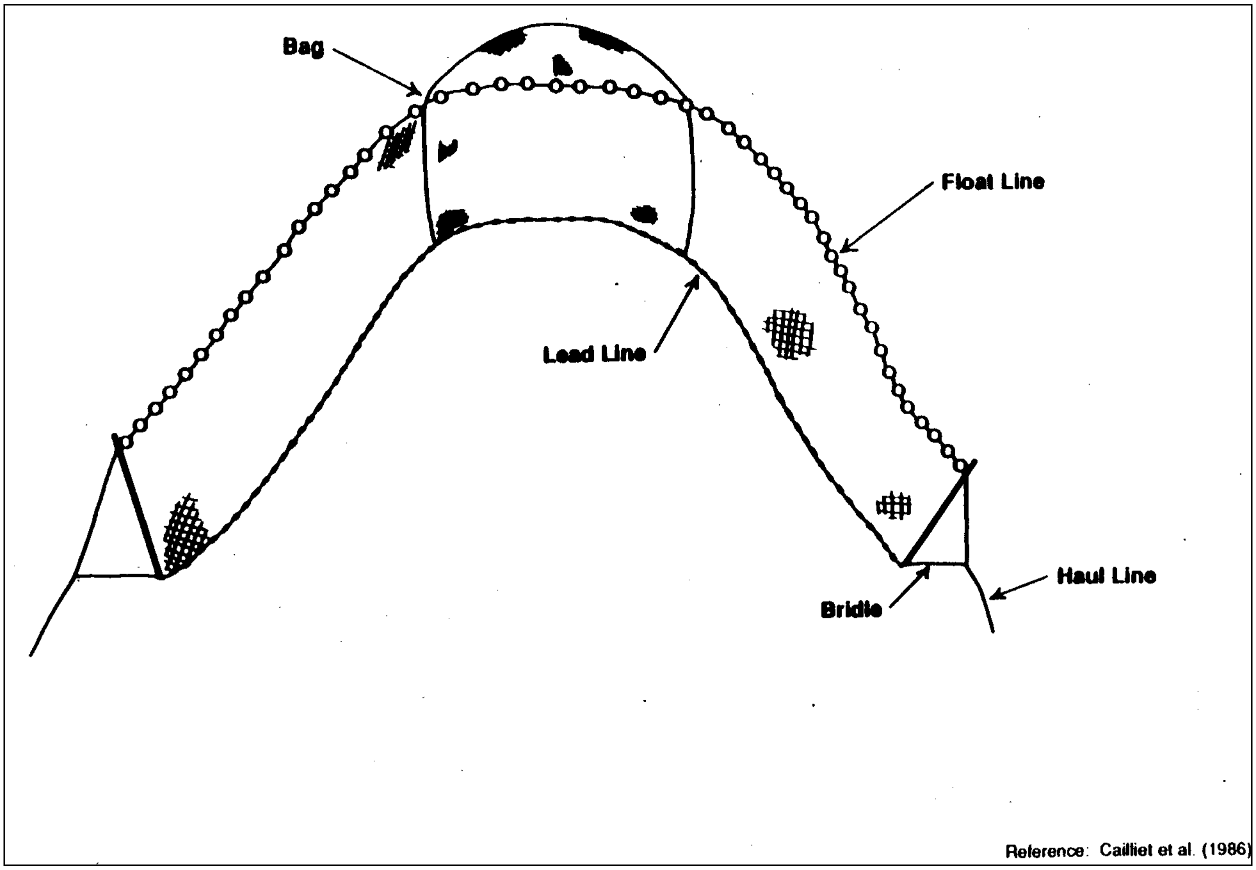


Figure 2. Diagram of 37-m beach seine.

7.6-m Otter Trawl

The 7.6-m otter trawl (also called the 25-ft otter trawl and the Marinovich trawl) is a two-panel, semi-balloon designed net. The basic layout of the net is shown in Figure 3, and the net plan is shown in Appendix B. The body of the net is constructed of 38-mm stretch mesh. The cod end is constructed of 32-mm stretch mesh lined with 6-mm stretch mesh, knotless netting. The headrope and footrope are 7.6 m and 8.1 m in length, respectively. Otter doors are attached to each side of the mouth of the net by short, leg extension lines (also termed dandylines). The otter doors are constructed of 19-mm plywood, with a steel shoe added for protection and weight. Lead weights are also attached to the otter doors. Total weight of an otter door is 23 kg. A 23-m long bridle, consisting of 19-mm braided nylon, attaches the otter doors to the trawl warp. The trawl warp consists of 8-mm diameter cable. Swivels on both ends of the bridle prevent the twisting of the trawl warp from affecting the net. The net is referred to as a single-wire trawl because it is towed by a single trawl warp deployed from a single winch.

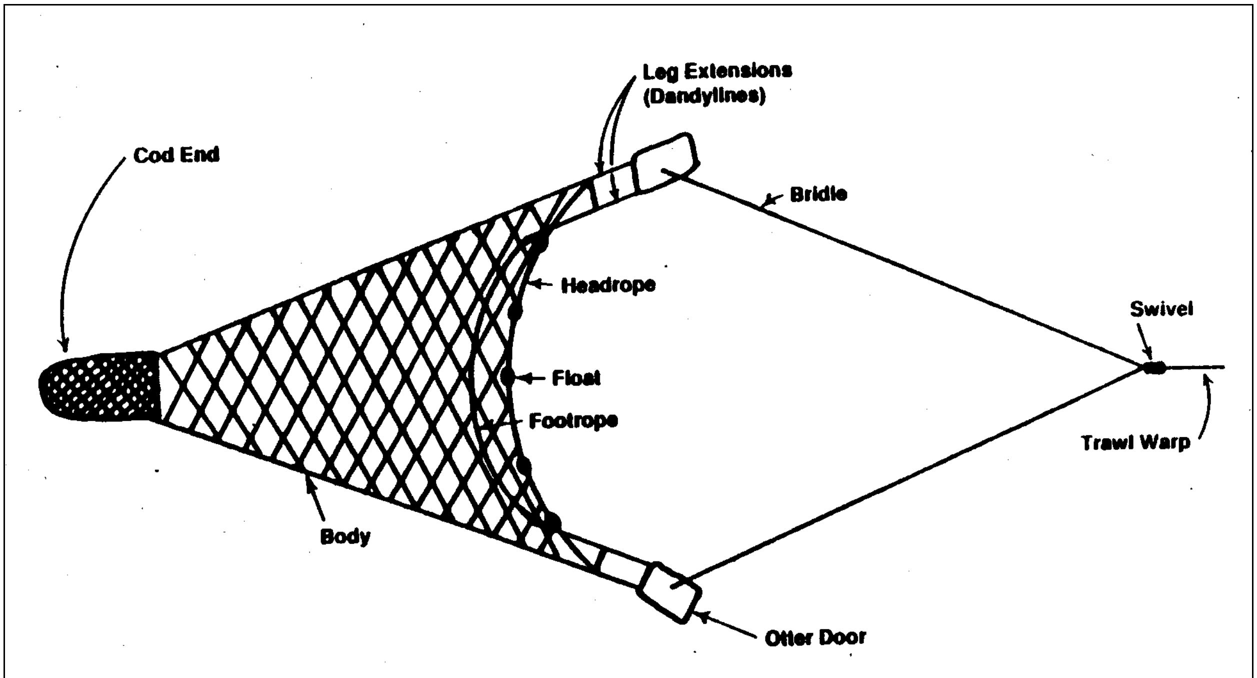


Figure 3. Diagram of 7.6-m otter trawl.

400-mesh Eastern Otter Trawl

The 400-mesh eastern otter trawl is the most commonly used double-wire research otter trawl (i.e., a trawl towed from two trawl warps and two winches) used in Puget Sound, although a wide variety of double-wire otter trawls has been developed for commercial applications. Different trawls have been developed for specific target assemblages and bottom topographies. Thus, the 400-mesh eastern otter trawl is not as standardized as is the 7.6-m otter trawl. The trawls may differ in foot rope length, dandyline/sweepline rigging, and door design. In addition, the equipment associated with deployment of the net (e.g., winches, otter doors, cables) is usually specific to each towing vessel. For example, an 18.3-m vessel, which is relatively small for towing this net, might have otter doors weighing 340 kg, while a larger vessel might have otter doors weighing 1,045 kg. These variations can influence the effective fishing width of the trawl. However, the 400-mesh eastern otter trawl can be deployed with mensuration gear that measures the width of the net, thereby enabling accurate determination of the area swept during a tow.

The 400-mesh eastern otter trawl is a two-panel, semi-balloon design. A diagram of this trawl is provided in Figure 4, and the net plan is provided in Appendix B. The following description was derived from a net intended for use by the Washington Department of Fisheries and National Marine Fisheries Service to monitor commercial fishes in Puget Sound. The body of the net is constructed of 10.2-cm polyethylene mesh. The cod end of the net is lined with 3.2-cm No. 18 nylon mesh. The headrope and footrope are 21.7 m and 28.7 m in length, respectively. Otter doors (typically vee-style doors for the 400-mesh eastern otter trawl) are attached to each side of the net by dandylines, a sweepline, and a tail chain. The vee doors are 1.5 × 2.1 m in size and weigh 363.6 kg. A separate trawl warp attaches each vee door to the towing vessel.

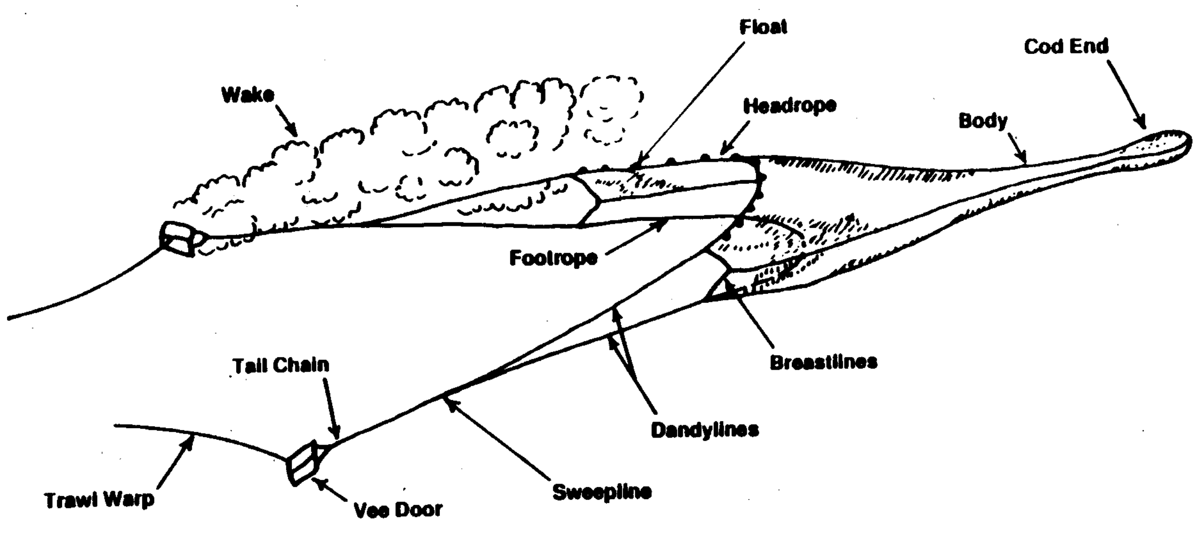


Figure 4. Diagram of 400-mesh eastern otter trawl.

ALTERNATE EQUIPMENT

It is recognized that other sampling equipment may function as effectively (or more effectively) than the recommended equipment for some target species or life history stages. However, the standard equipment recommended above has proved to be particularly effective for sampling a wide variety of demersal fish species and life history stages in Puget Sound. In addition, a large amount of historical information is based on that equipment. Alternate sampling equipment sometimes used in Puget Sound includes of the following:

- 9-m beach seine
- 3-m beam trawl.

Descriptions of the 9-m beach seine and 3-m beam trawl are provided below. Net plans are provided in Appendix B.

9-m Beach Seine

The 9-m beach seine is 8.8 m in total length, with 3.6-m wing lengths. Its design is similar to that of the 37-m beach seine (see Figure 2). The wings are constructed of 3.9-mm square, knotless mesh. The bag is constructed of 2.35-mm square, knotless mesh. Rigid poles are attached to the ends of the net to ensure that the net opening is the proper height. A 6.5-m check line is installed between the poles to ensure that the mouth of the net has a constant opening. The top line of the net has floatation, and the footrope has 55 lead weights (each weighing 113 g) attached to it.

3-m Beam Trawl

The 3-m beam trawl is a two-panel beam trawl. The trawl has a rigid beam in front of the net to maintain a fixed opening. A diagram of the net is provided in Figure 5, and the net plan is shown in Appendix B. The net is also described in detail in Gunderson and Ellis (1986). The body of the net is constructed of 14-mm square knotless nylon. The cod end is lined with 5.5-mm mesh. The headrope and footrope are 4.1 m and 5.1 m in length, respectively. The 3-m beam, which is constructed of 3.8-cm aluminum conduit or steel stock, is attached to the top and bottom of both sides of the mouth of the net, thereby providing the fixed opening. A beam bridle is connected to the trawl warp for towing. Mr. Ian Ellis, of Ellis Highline Systems, can be contacted for detailed information concerning the 3-m beam trawl.

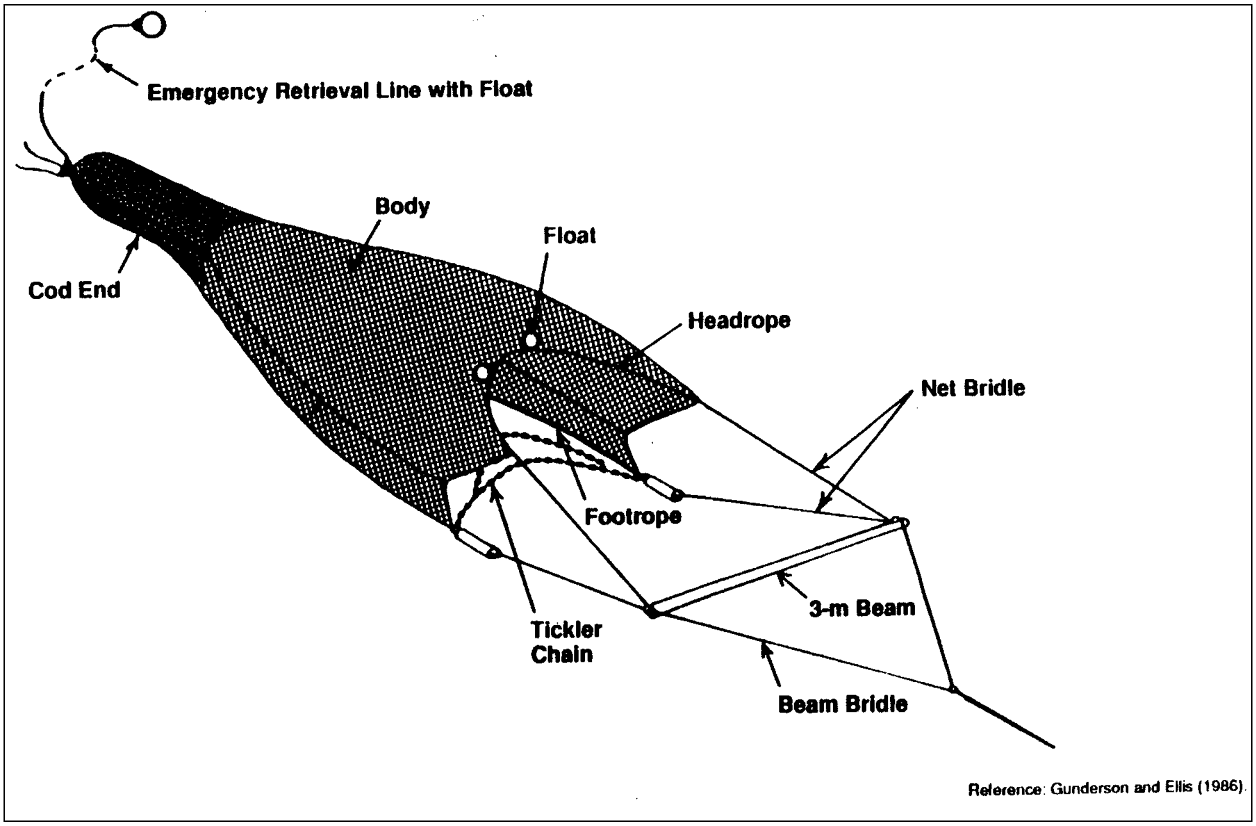


Figure 5. Diagram of 3-m beam trawl.

FIELD PROCEDURES

General guidelines concerning use of the recommended equipment are provided in this section. Deployment and retrieval are discussed in detail. Guidance concerning catch processing and field records is also provided.

GENERAL GUIDELINES FOR USE OF THE RECOMMENDED EQUIPMENT

Each of the sampling devices recommended for use in Puget Sound is best suited for a particular range of study objectives. Recommended equipment that are appropriate for various habitats, fish assemblages, and life history stages are summarized in Table 2. Juveniles and subadults that occupy intertidal and nearshore subtidal habitats are generally sampled using the 37-m beach seine. Large adults of commercial species that occupy deep water are most effectively sampled using the 400-mesh eastern otter trawl. The habitats and assemblages that can be sampled using the 7.6-m otter trawl are intermediate between, and overlap with, those of the 37-m beach seine and the 400-mesh eastern otter trawl.

The recommended equipment can be used effectively over a limited range of substrate types and within a limited range of environmental conditions. Use of the recommended equipment is generally successful in areas with fairly smooth bottoms. Use of these devices is generally not successful in rocky areas or areas with obstacles on the bottom. Heavy vegetation (i.e., greater than 50 percent cover) and steeply sloping bottoms (i.e., bottoms with slopes greater than 25 percent) may also interfere with the proper functioning of the recommended equipment. In areas with moderate currents, the nets should be hauled or towed against the current to maintain proper shape. However, none of the recommended nets should be used in areas where the current speed exceeds 2 km/h (1.1 kn).

DEPLOYMENT AND RETRIEVAL

This section provides guidance on deployment and retrieval of the recommended beach seines and trawls. Recommended hauling and towing speeds, distances, and durations are provided in Table 3. These parameters have been frequently used in studies of demersal fish assemblages in Puget Sound. Hauling and towing speeds influence net function in the water (e.g., width of the net opening, contact with the bottom) and the ability of fish to avoid capture. To ensure data comparability, it is important to use consistent hauling and towing speeds and distances among different studies. Additional recommendations for conducting quantitative sampling of demersal fishes in Puget Sound are presented in Appendix C.

TABLE 2. HABITATS, SPECIES ASSEMBLAGES, AND LIFE HISTORY STAGES OF DEMERSAL FISHES SAMPLED BY THE EQUIPMENT RECOMMENDED FOR USE IN PUGET SOUND

Habitat Code[a]	Habitat Depth	Examples of Species Assemblages	Primary Life Stages Sampled	Recommended Sampling Equipment
Nearshore Soft Bottom				
3a	Intertidal to 5 m	English sole, starry flounder	Juveniles & subadults	37-m beach seine
		Striped seaperch, shiner perch	Juveniles to adults	
3b	5-10 m	English sole, sand sole, rock sole	Juveniles & subadults	37-m beach seine and 7.6-m otter trawl
		Pacific staghorn sculpin	Juveniles to adults	
Offshore Soft Bottom				
4a	10-30 m	English sole, rock sole	Juveniles & subadults	7.6-m otter trawl
		Speckled sanddab, C-O sole	Juveniles to adults	
		Roughback sculpin	Juveniles to adults	
4b	30-70 m	English sole, rock sole, slender sole	Juveniles & subadults	7.6-m otter trawl
		Pacific tomcod, blackbelly eelpout	Juveniles to adults	
4c	>70 m	English sole, Dover sole, rex sole	Juveniles to adults	7.6-m otter trawl
		Pacific hake, slender sole	Juveniles to adults	
		Ratfish, Pacific tomcod, bluespotted poacher	Juveniles to adults	
4c	>70 m	English sole, Dover sole, rex sole	Adults (Commercial size)	400-mesh eastern otter trawl
		Slender sole, spiny dogfish, ratfish	Adults (Commercial size)	
		Pacific cod, Pacific hake, sablefish	Adults (Commercial size)	

[a] Habitat codes are shown in Figure 1.

TABLE 3. RECOMMENDED SPEEDS, DISTANCES, AND DURATIONS FOR HAULS AND TOWS OF SAMPLING EQUIPMENT FOR DEMERSAL FISHES IN PUGET SOUND

Sampling Equipment	Haul/Tow Speed	Haul/Tow Distance	Haul/Tow Duration (minutes)
37-m beach seine[a]	10 m/min	30,60,90 m[b]	3,6,9
9-m beach seine[c]	15 m/min	30 m[d]	2
7.6-m otter trawl[a]	4.6 km/hour (2.5 kn)	385 m	5
400-mesh eastern[a] otter trawl	5.6 km/hour (3.0 kn)	1.9 km	20
3-m beam trawl[c]	2.6 km/hour (1.4 kn)	215 m	5

[a] Recommended equipment

[b] Haul distances are perpendicular to shore.

[c] Alternate equipment

[d] Haul distance is parallel to shore.

Beach Seines

Standard Equipment: 37-m Beach Seine—As indicated in Table 2, the 37-m beach seine is used to collect small fish that inhabit the nearshore zone from the intertidal zone to a depth of approximately 10 m. Target species and life history stages frequently include juveniles and subadults of flatfishes, perches, and sculpins.

The net is set parallel to the shore using a small, rowed boat. Using a motor-powered vessel may disturb the fish and decrease the catch. One haul line and the net are carefully arranged in the boat to avoid tangling. A person standing on the beach holds the second haul line. This person should stand at one end of a 40-m distance that is marked along the beach. Two people are needed in the boat. One person rows, while the other person deploys the net. The boat is rowed directly away from shore. Distance from shore is measured using 10-m interval markings on the haul line. Nets are typically deployed at a 30-m distance from shore, although 60-m and 90-m distances are also used. When the boat reaches the appropriate distance from shore, it is turned at a right angle and the net is released while the boat is rowed parallel to the shore. If a current is present, the net should be released while the boat is rowed into the current. All of the net should be out of the boat and set in the water when the boat reaches the end of the 40-m distance that is marked on the beach. The second haul line is released while the boat is rowed back to shore. The second haul line is transferred to a person standing at the 40-m mark on the beach, and the boat is secured out of the path of the net.

Retrieval of the net involves pulling the net to shore. The net is pulled from both ends of the 40-m marked distance at a rate of approximately 10 m/min. Retrieval rates should be the same at both ends to ensure that the net is not pulled in at an oblique angle. When the net is 10 m from the beach, the individuals retrieving the net at each end approach one another so that the net opening is closed to approximately 12 m. Retrieval of the net is then completed. When the poles on the ends of the net breach the surface, one person on each end of the net should keep the end poles in contact with the bottom to ensure that the lead line remains in contact with the bottom, thereby preventing escapement under the net. When the net is nearly onshore, individuals should kneel at the edge of the water to hold the lead line on the bottom until the net is brought completely up on the beach.

Several factors should be considered when using the 37-m beach seine. This net is generally most effective when it is set at slack water on a minus tide (Moulton and Miller 1974). Replicate hauls should not be performed at the same position. If vegetation (e.g., eelgrass) is interfering with the net, and the water depth does not exceed the height of the net bag (i.e., 2.4 m), additional snap-on floats can be added to the float line to prevent the net from rolling onto the lead line.

Alternate Equipment: 9-m Beach Seine—The 9-m beach seine is used to collect small fishes that are concentrated at the water's edge. Angell et al. (1975) used this net to collect recently metamorphosed English sole. It has also been used extensively as a qualitative sampling device and to collect small fish for laboratory studies.

The net is set perpendicular to the beach and pulled manually along the beach. The person pulling the seaward end of the net typically wears chest waders or a wetsuit. The net is pulled at a speed of approximately 15 m/min through a previously measured distance of 30 m along the shore. After the net has been pulled over the 30-m distance, the seaward end of the net is brought to the shore by pivoting it around the onshore end, and the entire net is pulled onto the beach, where the catch is collected.

Trawls

Information on the deployment and retrieval of the 7.6-m otter trawl, 400-mesh eastern otter trawl, and 3-m beam trawl is provided below. Generally, all three pieces of equipment should be towed along depth contours at a relatively constant speed. If a current is present, then each net should be towed into the current.

Navigation—Accurate data on position and tow direction are needed to determine where the samples are collected and to calculate the area of bottom that is sampled. Determination of position and tow direction may be accomplished using various manual and electronic devices. Standard navigational equipment (e.g., Loran C, depth sounder, radar, optical range finder, sextant) is less accurate than specialized positioning equipment (e.g., microwave navigation systems, range-azimuth systems). The accuracy needed in a study should be determined by the study objectives. Generally, studies that involve repeated occupation and sampling of specific sites on the bottom require more accurate positioning than surveys used to characterize general conditions in an area. Because trawling studies generally involve characterizing relatively large areas, the degree of accuracy required for determining position and direction is usually less than that required for studies focused on much smaller areas (e.g., studies of sediment contamination or benthic macroinvertebrate assemblages). Additional information on navigation is available in the Puget Sound Estuary Program (PSEP) protocols document on positioning (PSEP 1986).

At a minimum, positional data should be obtained at the beginning and end of each tow, as well as at any point where haul direction changes. When using sampling vessels that lack sophisticated electronic devices for determining position, it may be convenient to mark the positions of the beginning and end of a transect with buoys, and then measure the distance between the buoys with an optical range finder.

Data on speed through the water and speed over the ground are needed for proper trawl deployment and determination of the area sampled during a tow. Speed through the water can be measured using a calibrated knotmeter, or it can be estimated from the engine speed, which is measured using a tachometer. Using a tachometer to estimate speed through the water may be inaccurate, and requires calibration between engine speed and boat speed when a trawl is being towed. Speed over the bottom is determined by dividing the distance covered between the beginning and the end of a tow by the tow duration.

Standard Equipment: 7.6-m Otter Trawl—As indicated in Table 2, the 7.6-m otter trawl is used to collect juvenile, subadult, and adult bottom fish at depths ranging from 5 to >70 m. The species that are commonly collected using this device include several flatfishes, sculpins, hake, and tomcod.

Deployment and retrieval of the 7.6-m otter trawl are affected by the size, equipment, and instrumentation of the sampling vessel. It is recommended that smaller sampling vessels be operated only in relatively sheltered and shallow waters (i.e., <30-m depth) because of both safety and technical considerations. A large vessel typically has a boom for handling the net and a winch that can carry 8-mm cable for the trawl warp. A smaller vessel may lack a boom and may have a mechanical winch that can only carry 6-mm cable for the trawl warp. Also, the length of cable that can be carried by a small vessel is typically less than that carried by a larger vessel. The minimum size for a towing vessel is determined by the ability of the vessel to maintain the recommended towing speed of 4.6 km/h (2.5 kn). The 7.6-m otter trawl has been deployed using a vessel as small as a 5.2 m in length and powered by a 70 horsepower outboard motor.

The basic procedure for deploying the 7.6-m otter trawl is to carefully pay out the net (cod end first), and allow it to sink while the towing vessel moves slowly forward. Initially, the trawl is towed for a short distance on the surface to confirm that it is deployed properly. The trawl warp is then released at a speed slightly slower than the forward speed of the towing vessel (i.e., to ensure that the trawl remains properly oriented), and the trawl gradually sinks. When the proper scope has been reached [i.e., the proper amount of towing cable (warp) has been released], the trawl is assumed to have reached the bottom. The recommended length of wire out is depicted for depths ranging from 0 to 200 m in Figure 6. It generally is possible to confirm that the trawl is being towed along the bottom because vibrations from contact with the bottom are transmitted up through the trawl warp. The recommended standard tow distance is 385 m at a ground speed of 4.6 km/h (2.5 kn) (Table 3).

The procedures for net retrieval are influenced by the size of the sampling vessel. In relatively large boats, trawl retrieval is initiated by increasing the speed of the towing vessel. This causes the trawl to rise off the bottom, which stops the collection of demersal fishes. The tow cable and bridle are spooled onto the winch until the otter doors reach a trawl block mounted at the end of the boom. The net is then quickly brought on board by hand to minimize catch escapement. Once the net is on board the vessel, the cod end is opened and the catch is removed.

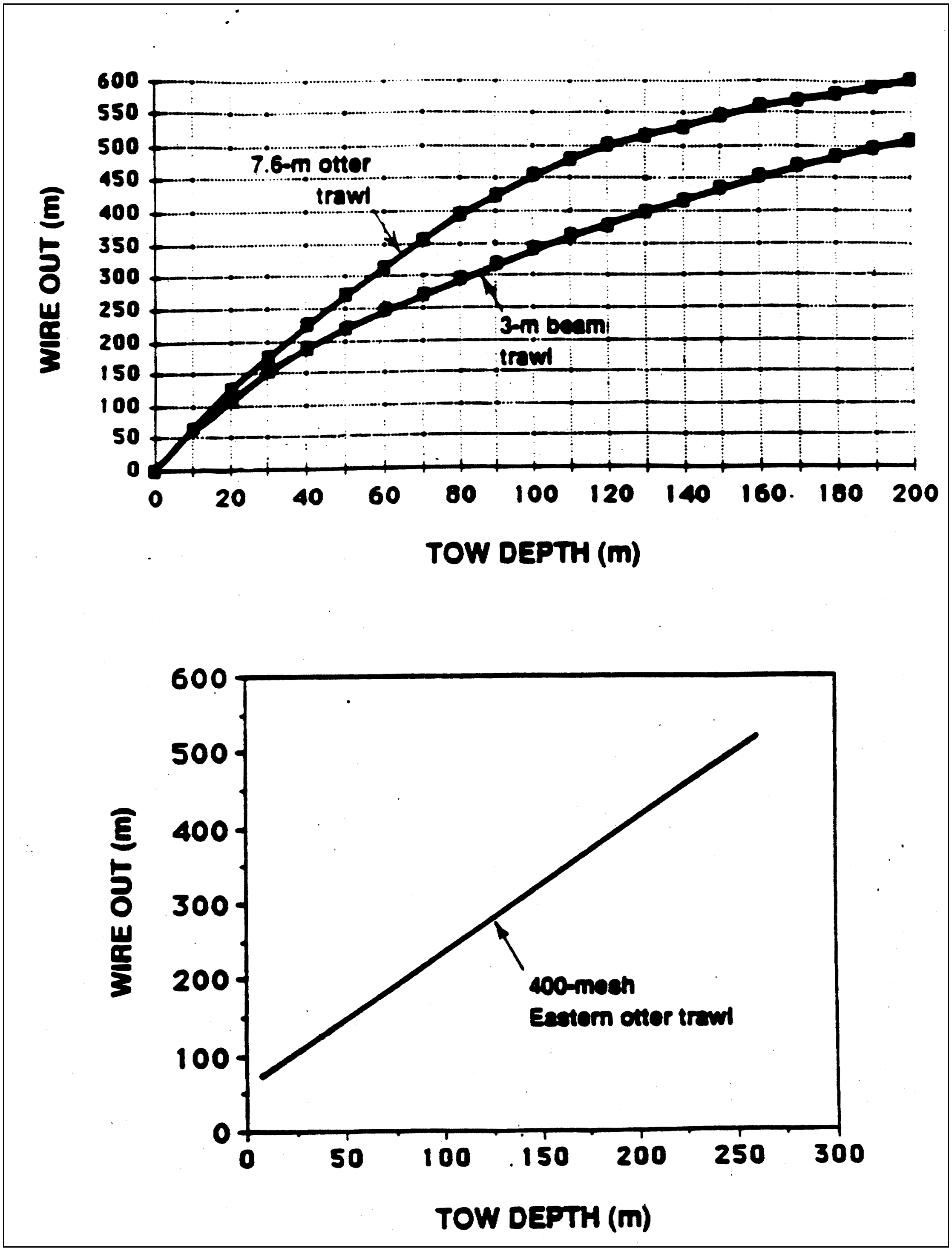


Figure 6. Wire out as a function of two depth (i.e. s, scope) for the 7.6-m trawl, 3-m beam trawel, and 400-mesh eastern otter trawl.

In a smaller vessel, trawl retrieval involves pulling the trawl up as quickly as possible while using the engine to maintain minimal headway. Because small vessels typically do not have a boom, the otter doors and net are brought on board by hand after the tow cable and bridle have been spooled onto the winch. Quick retrieval is essential for minimizing potential loss of the catch. Once the net is on board the vessel, the cod end is opened and the catch is removed. If the trawl has been deployed at a depth >30 m, pulling on the trawl with the winch may actually pull the boat backwards toward the trawl, while the trawl remains stationary on the bottom. In this situation, some of the catch may escape.

Standard Equipment: 400-mesh Eastern Otter Trawl—The doors, cable, and net of the 400-mesh eastern otter trawl are heavy, and can be dangerous if handled improperly. Thus, this trawl should always be operated by experienced personnel.

As indicated in Table 2, the 400-mesh eastern otter trawl is used at depths >70 m, and adult specimens are typically collected. Target species often include flatfishes, dogfish, ratfish, cod, hake, and sablefish. This trawl does not function effectively at sites with steeply sloping (i.e., >23°) bottoms.

Although the 400-mesh eastern otter trawl is primarily used on smooth bottoms, it is possible to add roller gear to this trawl for use on relatively rough bottoms. However, the roller gear substantially alters fishing characteristics of the trawl, so that data obtained using roller gear cannot be compared with data obtained without using roller gear.

Because the 400-mesh eastern otter trawl is substantially larger than the 7.6-m otter trawl, deployment and retrieval of this net require a relatively large and powerful vessel. At a minimum, the sampling vessel must be able to maintain the recommended standard towing speed when the net is deployed. Sampling vessels for this trawl typically have an engine with a minimum of 400-500 horsepower.

The vessel used to deploy the 400-mesh eastern otter trawl should have a separate winch for each trawl warp. To begin deployment, the net is spooled off the net reel and lowered into the water (cod end first), until the sweeplines can be attached to the doors. The rest of the net is then lowered overboard, the vee doors are unhooked from their stanchions and lowered into the water, and the net is set by slowly moving the sampling vessel forward. Trawl warp is winched out at approximately the same speed as the vessel is moving, so that the trawl can sink straight down as the vessel moves forward. Trawl warp is released until the proper scope is achieved (Figure 6). The amount of trawl warp to be released should be determined before deployment begins. A settling period is allowed, during which the trawl sinks to the bottom and spreads. An acoustic depth sounder can be attached to the trawl to determine when the net reaches the bottom. After the net reaches the bottom, the towing vessel starts to tow the net over a predetermined course. It is generally possible to confirm that the trawl is being towed along the bottom because vibrations from contact with the bottom are transmitted along the trawl warp. The trawl is assumed to start fishing when the towing vessel begins to tow it. The recommended standard tow speed is 5.6 km/h (3.0 kn).

Because the 400-mesh eastern otter trawl is more difficult to deploy than the 7.6-m otter trawl, longer tows are generally conducted to obtain a larger catch per tow (see Table 3). Along an open coast, a standard tow may last 20 min and cover a distance of 1.9 km. Although replication of tows is generally recommended, it is more difficult to achieve using the 400-mesh eastern otter trawl than the 7.6-m otter trawl.

The position for the end of the tow is defined as the position where the net was lifted from the bottom and ceased effective fishing (i.e., when retrieval begins). This position can be detected using the depth sounder that is a component of the mensuration equipment of the net (i.e., if this equipment is used). At the end of the tow, the 400-mesh eastern otter trawl is retrieved by spooling the trawl warp onto the winches until the doors can be rehooked to their stanchions. After the doors are hooked to their stanchions, the sweeplines are moved back to the net reel, and the net is wound onto the net reel. Once the net is on board the vessel, the cod end is opened and the catch is removed.

The Puget Sound Ambient Monitoring Program (PSAMP) Fish Task uses the 400-mesh eastern otter trawl at depths <70 m, where Table 2 would recommend use of the 7.6-m otter trawl. Although the data collected by the two trawls are not comparable, there are several reasons for this alternate use of the 400-mesh eastern otter trawl by the PSAMP Fish Task. One reason is the practicality of being able to sample in both deep and shallow waters without having to change gear. Another reason is efficiency. One of the PSAMP Fish Task objectives is to study fish health and its relationship to contaminant bioaccumulation. Meeting this objective requires collection of a large number of relatively large fish, for which the 400-mesh eastern otter trawl is a more efficient gear to use than the 7.6-m otter trawl.

Alternate Equipment: 3-m Beam Trawl—The 3-m beam trawl was designed to sample juvenile crabs and flatfishes (Gunderson and Ellis 1986). The 3-m beam trawl is not effective as a general sampler of fish as the 7.6-m otter trawl. The advantage of using the 3-m beam trawl is that it has a fixed width for the mouth of the net, thereby enabling better repeatability of net functioning. However, the 3-m beam trawl does not yield data that are directly comparable with data obtained using the 7.6-m otter trawl. Therefore, the 3-m beam trawl should not be used in studies that could involve direct comparisons with data obtained using the 7.6-m otter trawl.

As with the 7.6-m otter trawl, deployment and retrieval of the 3-m beam trawl are affected by the size, equipment, and instrumentation of the sampling vessel. Smaller vessels should only be used in relatively sheltered and shallow waters (i.e., <30-m depth) because of both safety and technical considerations (e.g., length and size of cable). The vessel must be capable of maintaining the recommended towing speed of 2.6 km/h (1.4 kn). The 3-m beam trawl has been deployed using a vessel as small as 5.2 m in length, and powered by a 70 horsepower outboard motor.

Deployment is initiated by carefully paying out the net (cod end first). The net may be detached from the beam between tows for handling purposes. The trawl is towed on the surface for a short distance to confirm proper configuration. The trawl warp is then released at the same speed as the forward movement of the sampling vessel, and the trawl sinks. When the proper scope has been reached, the trawl is assumed to have reached the bottom. The recommended length of wire out is depicted for depths ranging from 0 to 200 m in Figure 6. It generally is possible to confirm that the trawl is being towed along the bottom because vibrations from contact with the bottom are transmitted along the trawl warp. After the trawl reaches the bottom, it is towed at a predetermined ground speed. As indicated in Table 3, the recommended standard tow distance is 215 m at a ground speed of 2.6 km/h (1.4 kn).

The procedures used for deployment differ between small and large sampling vessels. The primary problem affecting deployment from small vessels, especially those powered with outboard or inboard/outboard engines, is to avoid tangling the net in the propeller. Hence in small vessels, the net is deployed over the side. The vessel should be positioned downwind from the net, so that any wind will push the vessel away from, rather than over, the net. While the trawl warp is held away from the vessel, the vessel is maneuvered so that the net is laid out behind it before the trawl warp is deployed. Deployment of the 3-m beam trawl from large (e.g., inboard-powered) vessels may be more convenient than from small vessels because the net is simply set off the stern (cod end first), with the boat maintaining forward speed.

Trawl retrieval is initiated by engaging the winch when the proper distance has been covered. Because of possible escapement of the catch, the net should not be allowed to pull the towing vessel backwards during retrieval. This problem is most likely to occur with a small vessel that is relatively light. For small vessels, it is recommended that vessel speed be maintained at the same speed as, or slightly faster than, the net recovery speed. For large vessels, the vessel position should at least be maintained, or the vessel can be moved at a slight forward speed. The procedure for net retrieval is the reverse of that for net deployment. The net is retrieved by hand over the side in small vessels and over the stern in large vessels. Some catches may require washing to remove sediments from the net. Washing can be achieved by towing the net at a moderate speed behind the boat or by careful agitation of the net at the side of the boat. Once the net is on board the vessel, the cod end is opened and the catch is removed.

CATCH PROCESSING

After the catch is brought on shore (when using a beach seine) or on board the sampling vessel (when using a trawl), it is usually returned to the laboratory for processing and analysis. Catches may also be sorted and processed in the field. However, unless these operations are required to be conducted in the field by the study design, it is recommended that they should not be allowed to occupy time that is needed for additional collection efforts. Generally, time may be available for catch processing in the field if only one or two target species are required for a particular project.

The recommendations for catch processing provided below are appropriate for projects intended to provide descriptive ecological data. These methods are not appropriate for use in studies of chemical contaminants in fish. In bioaccumulation studies, it is critical to avoid spurious contamination of specimens during collection, transportation, and processing. Consult the PSEP protocol documents on metals (PSEP 1988a), organic compounds (PSEP 1988b), and fish pathology (PSEP 1987) for additional information.

For studies involving ecological analyses (and not involving chemical analyses) and laboratory processing, the catch should be double-bagged in heavy-duty plastic bags and double-labeled (i.e., one label inside the bags and one label on the outside of the bags) for return to the laboratory. The catch may be held on ice for a maximum of 1 day (except for studies requiring analysis of stomach contents). Longer periods of storage or transportation require freezing of the catch.

Although it is recommended that entire catches be processed, so that all available information can be obtained quantitatively from the catch, very large catches may require subsampling in the field. Large catches often are dominated by one species that happens to be unusually abundant at the study site. The objective in subsampling is to obtain a subsample that accurately represents the complete catch. The details of the subsampling procedure used for a particular study should always be recorded. Investigators may be forced to adapt to unforeseen situations in the field (e.g., bad weather; unexpected species composition of catch; lack of time, equipment, space, or manpower).

A subsampling method (for a single species) described by Westrheim (1967) involves dividing the entire catch into buckets or baskets that have been placed into multiple rows. The buckets are filled by row, starting with the front row. For surveys intended to quantify demersal fish assemblages, specimens of each species are allocated randomly to the buckets. The subsample is then collected after the catch has been completely divided. For surveys intended to collect only one or two target species, these species are selectively allocated to the buckets, while the remainder of the catch is discarded. The following guidelines are used for selecting the specimens that will make up the subsample:

- Take an equal portion of the subsample from each completely filled row of buckets

- Take a total of approximately 200 fish

- Try to keep the bucket as a sampling unit; for catches that consist of small fish, it may be necessary to take only one bucket, or even just the top portion of one bucket, from each row.

The method used by the Washington Department of Fisheries for subsampling catches (that weigh more than 900 kg) from the 400-mesh eastern otter trawl is as follows:

- Bring the entire catch aboard in the trawl net
- With a load cell, weigh the entire catch and net, making sure the net is clear of the deck
- Empty a portion of the net contents into a confined area on deck that has been lined with a cargo net (which has been made to hold about 1,100 kg). A minimum of 900 kg or a 20 percent subsample, whichever is greater, is desirable.
- Weigh the empty trawl net
- Lift the cargo net containing the subsample from the deck and empty it onto the sorting table
- Discard the remaining catch overboard
- Sort the subsample on the table in the usual manner except that the weight of any debris in the subsample must be recorded.

FIELD RECORDS

Thorough documentation of the work done in the field is necessary to interpret the results of a field survey. For fish trawling studies, it is advisable to have preprinted, waterproof data forms and writing implements that can function while wet and produce indelible markings.

The following information is recommended for inclusion on the field record for every tow. Additional information may be required for specific projects. Consult Puget Sound Water Quality Authority (PSWQA 1988) for data reporting requirements and data transfer formats for studies that will be submitted to the Puget Sound Ambient Monitoring Program database.

- Project name
- Date
- Name of towing vessel (if applicable)
- Station identifier (e.g., name, code)
- Names of chief scientist and data recorder
- Gear type
- Tow or haul number

- Time of day for start and end of tow or haul
- Tow duration (if applicable)
- Distance covered by tow or haul
- Station depth (or depth range)
- Location of start and end of tow or haul (latitude, longitude, distances from fixed points)
- Speed over the ground for the tow (if applicable)
- Current speed (if available)
- Tidal stage (if available)
- Compass heading during tow (if applicable)
- Environmental conditions (e.g., water temperature at tow depth, weather, sea state)
- Remarks (e.g., presence of invertebrates, algae, and miscellaneous items caught; subsampling methods; anything that may influence data quality and tow acceptability).

LABORATORY PROCEDURES

Laboratory work consists of obtaining the data needed for the particular project by processing the specimens. To generate data that will be useful for analysis of long-term trends, it is recommended that as complete a data set as possible be obtained from every collection. However, based on project objectives, the project manager should determine the procedures to be followed and the data to be obtained. Some projects may require basic descriptive information on the sampled assemblage (e.g., presence/absence of species, numbers of individuals), whereas other projects may require detailed information concerning the assemblage, a particular species, or the health of individuals.

LABORATORY METHODS

The following guidelines are provided for conducting laboratory analysis of beach seine and trawl collections. Primary considerations are attention to detail and involvement of experienced personnel who are knowledgeable about the taxonomy and ecology of demersal fish assemblages in Puget Sound. The laboratory methods are not complex and do not generally require expensive, specialized equipment.

The best reference for species identifications of Puget Sound fishes is Hart (1973). Lamb and Edgell (1986), Eschmeyer et al. (1983), and DeLacy et al. (1972) are also useful for preliminary species identifications. It may be useful to have pictures of individuals of known life history stages or with known health anomalies for identifying life history stages or pathological conditions. Voucher specimens over a representative size range may be retained for verification of species identifications. Voucher specimens can be preserved in 10 percent buffered formalin. After laboratory analysis and selection of voucher specimens, the catch is usually discarded.

Weight (wet) and length measurements should be obtained with accuracies that are appropriate to project objectives. For example, a study of juvenile English sole might require weight and length data be measured to the nearest 0.1 g and 1 mm, respectively. However, a study intended to provide data on a gross scale for preliminary assessment of populations of adult English sole might require that weight and length data be measured to the nearest 1.0 g and 10 mm, respectively.

It is recommended that total length be used as the primary measure of fish length. Total length is the length from the anterior-most part of the fish to the tip of the longest caudal fin ray. Two kinds of total length can be measured (Anderson and Gutreuter 1983). Maximum total length is determined when the lobes of the caudal fin are compressed dorsoventrally, whereas natural total length is measured when the caudal fin is in its natural state. To be consistent with the convention used by most fishery investigations in the United States, maximum total length should be measured (Anderson and Gutreuter 1983).

For fishes that occur in relatively large numbers, individuals may be classified into size classes rather than measured exactly. This procedure can reduce processing time considerably. If size classes are used, it is recommended that they differ by no more than 1 cm each. Furthermore, it is recommended that each size class be measured from 0.5-cm value to the next. For example, a 10-cm size would include fish from 9.50 to 10.49 cm.

In some cases, erosion of the caudal fin in a substantial segment of a population may require that a measurement other than total length be used for affected individuals. If this occurs, it is recommended that maximum standard length be used as a substitute. Standard length is the length from the anterior-most part of the fish to the posterior end of the hypural bone. Anderson and Gutreuter (1983) state that in practice, standard length may be measured to some external feature such as the last lateral line scale, the end of the fleshy caudal peduncle, or the midline of a crease that forms when the tail is bent sharply. Standard length can be related to total length by developing a regression relationship between these two measures for a sample that covers the complete length range observed in the population.

Data on fish sex can often be obtained simply by inspection by an experienced fisheries biologist. Data on sexual maturity may require microscopic examination of the gonads.

Some kinds of information on fish health (e.g., fin erosion) can be obtained by visual inspection. Other kinds of health data may require extensive analysis. Consult the PSEP protocol document on fish pathology (PSEP 1987) for additional information on this subject.

LABORATORY RECORDS

It is essential that the data generated in the laboratory are recorded accurately and permanently, and that the laboratory data can be related directly to the field data. The laboratory data should be recorded on preprinted data forms. These forms need not be waterproof.

Depending on the amount of detail needed for a project, the following data forms may be needed. A "catch form" is used to record the data on a sample of fish and a "specimen form" is used to record data on individual specimens. Every page of the data forms should include space for key identifiers to link different forms and pages together. The key identifiers include project name, date, station code, depth, and tow number.

Much of the information on a catch form is simply transferred from the appropriate field record. Consult Puget Sound Water Quality Authority (PSWQA 1988) for data reporting requirements and data transfer formats for studies that will be submitted to the Puget Sound Ambient Monitoring Program database. Although specific projects may require additional information, a typical catch form should include the items listed below:

- Project name
- Dates of collection and analysis
- Name of towing vessel (if applicable)
- Names of chief scientist and data recorder
- Station identifier (name, code)
- Equipment used (e.g., 7.6-m otter trawl)
- Tow or haul number
- Depth of tow or haul
- Tow or haul attributes (distance, ground speed, duration)
- Species names and numbers caught
- Life history stages and numbers caught
- Subsampling method (if any)
- Total weight for the life history stage of the species
- Remarks (e.g., physical abnormalities, disease, QA/QC problems).

Depending on project objectives, a typical specimen form should include at least the following items:

- Species name
- Life history stage
- Total length
- Weight (wet)

- Sex (male, female, indeterminate)

- Stage of sexual development

- Age (if determined)

- Visible abnormalities (e.g., health problems such as fin erosion, skin ulcers, skeletal anomalies, neoplasms, and parasites).

In addition, the specimen form should include the information needed to identify the origin of the specimen (i.e., project name, dates of collection and analysis, station identifier, haul number, names of chief scientist and data recorder).

The above guidelines are not meant to be comprehensive. Some projects may have additional data requirements (e.g., liver histopathology, stomach contents) that are not covered in this document.

QUALITY ASSURANCE/QUALITY CONTROL

The most important aspect of QA/QC in studies of demersal fish assemblages is professional competence. In the field, QA/QC issues primarily involve determining that the sampling equipment is functioning properly. In the laboratory, the primary concern is with accuracy of the data. Investigators, vessel captains, and crew must be familiar with the sampling equipment. In both the field and the laboratory, careful recordkeeping is essential for adequate QA/QC.

QUALITY ASSURANCE/QUALITY CONTROL IN THE FIELD

In the field, it is necessary to confirm that locations are accurately determined, that sampling equipment is towed as intended, and that sampling equipment is functioning correctly.

There are no specific QA/QC guidelines for determining beach seine station locations. Investigators should be able to read maps and charts. For long-term studies, experienced personnel that have sampled a particular station previously should be responsible for accurately relocating that station.

QA/QC guidelines for determining trawling station locations involve the use of navigational instruments. Manufacturer's instructions should be carefully followed. The proper functioning and calibration of navigational instruments should be confirmed at the beginning of every cruise. One way to assess these factors is to check the readings of navigational instruments at a known location (e.g., a dock that is plotted on navigational charts). More information concerning QA/QC of shipboard navigation is available in the PSEP protocol document on station positioning (PSEP 1986).

All seine and trawl equipment should be checked before each sampling trip to ensure all dimensions are close to design specifications and that the equipment is in sound operating condition. During a sampling trip, nets should be continually checked for holes, and the associated equipment should be watched to detect alterations that could affect function. Damaged equipment that cannot be restored to design specifications should be replaced. For trawling surveys, it is recommended that two backup trawl assemblies (i.e., nets, doors, bridles) be on board the sampling vessel to replace lost or damaged equipment.

It is necessary to confirm that sampling equipment is functioning properly when deployed. If currents are observed in the study area, it should be confirmed that the current speed does not exceed 2 km/h (1.1 kn) before sampling is conducted. Actual tow speed should be within 25 percent of the recommended tow speed. Tow speed is determined after a tow is completed, and is calculated as distance divided by time (i.e., speed over the bottom). Tows that are not conducted within 25 percent of the recommended tow speed should be repeated.

To the extent possible, it should be confirmed that trawls and seines are in contact with the bottom during each tow. At the start of each tow, it should be confirmed that the correct amount of trawl warp has been released. Mensuration equipment can be monitored to determine whether the 400-mesh eastern otter trawl is on the bottom. Checks to confirm that the 7.6-m otter trawl and the 3-m beam trawl are on the bottom involve feeling vibrations in the trawl warp. The vibrations are generated by the movements of the net over the substrate. A net that is being towed off the bottom moves through the water more smoothly.

After a tow is completed, tow acceptability should be determined. Specific, quantitative QA/QC criteria for tow acceptability are not available. Instead, QA/QC for tow acceptability depend on the judgment of an experienced person that the equipment functioned properly. Tows influenced by questionable net functioning should be repeated. Factors to consider when judging net functioning include the following:

- Clogging—Fishing efficiency could be compromised if the net is filled with macrophytes, invertebrates, or debris.
- Hang ups—Part or all of the catch could escape when the net is hung up on an obstruction.
- Deployment—If the net is tangled, twisted, or flipped over when it is brought up to the surface, the net is unlikely to have functioned properly.
- Tearing—Badly torn nets, particularly those torn near the cod end, cannot retain specimens with normal efficiency.
- Contents—Nets that are empty or contain an unexpectedly low number of fish at the end of a tow probably were not in contact with the bottom.

In some situations, samples are processed when the net may not have functioned properly. This is generally not recommended, but may be acceptable for some project objectives. For example, a tow could be accepted even when the net did not function properly when the objective was only to obtain specimens for laboratory studies. However, in no cases should a sample be considered ecologically quantitative when net function is questionable.

QUALITY ASSURANCE/QUALITY CONTROL IN THE LABORATORY

QA/QC in the laboratory is primarily concerned with confirming that mistakes are not made during sample processing. An experienced scientist should be responsible for the laboratory work. Personnel should confirm the identity of each sample before it is analyzed. Questionable identifications of species and life history stages should be confirmed by a competent specialist. In addition, laboratory instruments (e.g., scales, microscopes) should be calibrated according to the manufacturer's specifications.

DATA REPORTING REQUIREMENTS

Data reporting requirements should be defined by the project manager before the study design can be considered complete. It may be useful to report both raw and summarized data for particular project objectives. Project objectives may require summarizing the data by reporting the number of species caught, relative species abundance, size-frequency or age-frequency distributions, stomach contents, or frequency of disease.

Reports of raw data should include the following information for each sample:

- Project name
- Collection date
- Station identifier (name, code)
- Sampling gear (e.g., 7.6-m otter trawl)
- Tow or haul number
- Station depth
- Tow or haul attributes (distance covered, ground speed, duration)
- Species names and numbers caught (by life history stage if possible)
- Subsampling method (if any)
- Total weight for the life history stage of the species
- Remarks (e.g., physical abnormalities, disease, any QA/QC problems).

Data reported for individual specimens should include the items needed to identify the sample from which the individual came and the following information:

- Species name

- Life history stage (if possible)
- Length
- Weight
- Sex
- Stage of sexual maturity
- Age (if determined)
- Visible abnormalities (e.g., health problems such as fin erosion, skin ulcers, skeletal anomalies, neoplasms, and parasites)
- Remarks (e.g., subsampling, equipment malfunction, any QA/QC problems).

The raw data can be summarized in any of the following units:

- Catch per area swept by the net (e.g., kg per hectare)
- Catch per unit effort (e.g., number per standard tow)
- Catch per time fished (e.g., number per hour).

Although all of the above units have been used in the past, catch per area swept by the net is recommended in this document because it is probably the most useful unit. The units used for a particular study should be clearly indicated with the data. Summarized data should also include information on ground speed of the tow, tow distance, sampling equipment (e.g., 7.6-m otter trawl), and a methods reference (e.g., PSEP protocols).

If data are to be reported in computerized form, standard computerized codes and formats may facilitate data management and exchange. The National Oceanographic Data Center (NODC) has published recommended codes and formats. The Puget Sound Ambient Monitoring Program has published a modified NODC format for use in Puget Sound (PSWQA 1988). Its use is recommended to facilitate the comparability of data from various studies in Puget Sound.

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APPENDIX A

Summary of Long-Term Demersal Fish Studies for Puget Sound

TABLE A-1. SUMMARY OF MULTIYEAR (≥ 2 YEARS) TRAWL AND BEACH SEINE STUDIES CONDUCTED IN PUGET SOUND

Investigator and Affiliation	Years	Gear Type	Locations
DeLacy University of Washington	1949-1976	400-mesh eastern and other otter trawls	~ 15 areas of southern and northern Puget Sound
Miller University of Washington	1969-1988	4.9 and 7.6-m otter trawls	~ 13 areas of southern and northern Puget Sound
English University of Washington	1964-1978	3-m rigid-frame beam trawl	Multiple areas in southern and northern Puget Sound
DeLacy and Miller University of Washington	1949-1976	9-m and 37-m beach seines and 7.6-m and 400-mesh eastern otter trawls	Multiple areas in central Puget Sound
Friday Harbor Laboratories	1950-1987	9-m and 37-m beach seines and 7.6-m and 400-mesh eastern otter trawls	San Juan Islands
WA Department of Fisheries	1950-1988	Commercial otter trawls, 400-mesh eastern and others	Puget Sound
U.S. Navy	1973-1974	7.6-m otter trawl	Hood Canal at Bangor
Ames et al Northwest and Alaska Fisheries Center, NOAA	1973-1974	7.6-m otter trawl	Port Gardner
Dinnel et al. University of Washington	1986-1987	7.6-m otter trawl and 3-m beam trawl	Port Gardner
Gunderson University of Washington	1980-1988	400-mesh eastern otter trawl	Case Inlet

Reference: Moulton and Miller (1987).

APPENDIX B

Net Plans for Standard and Alternate Beach Seines and Trawls

(Net plans are provided for the 37-m beach seine, 9-m beach seine, 7.6-m otter trawl, 400-mesh eastern otter trawl, and the 3-m beam trawl. Net plans contain the measurements and specifications for net construction.)

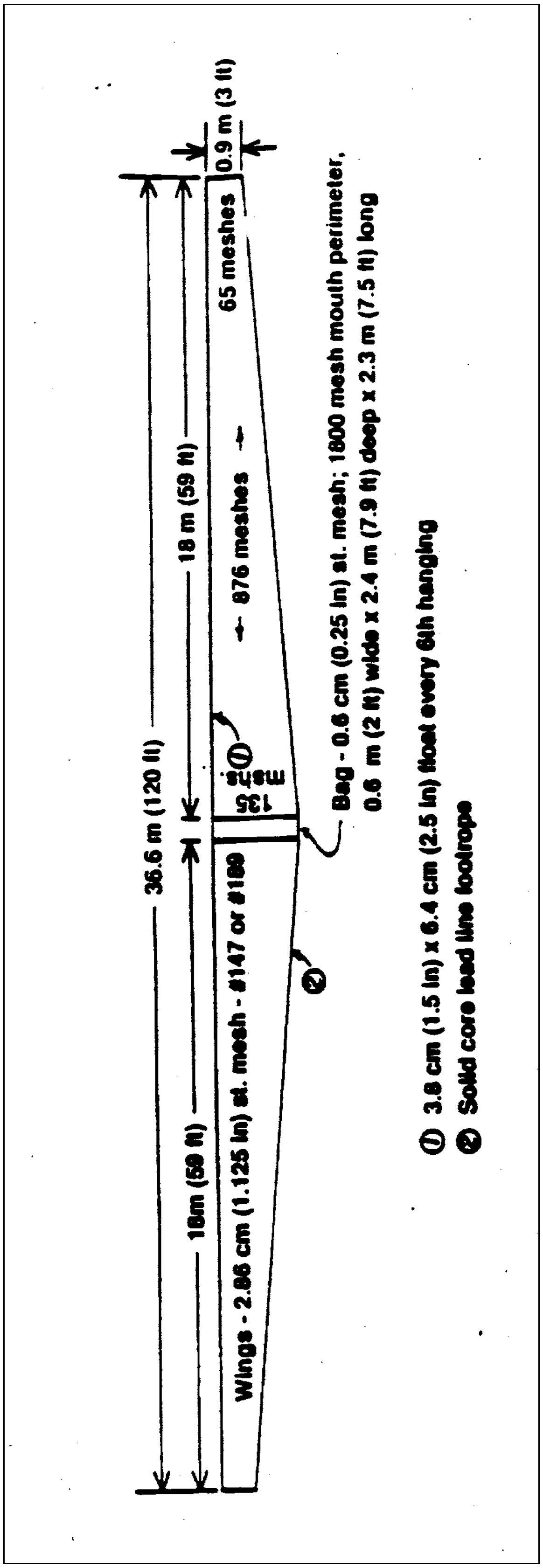


Figure B-1. Net plan for the 37-m beach seine.

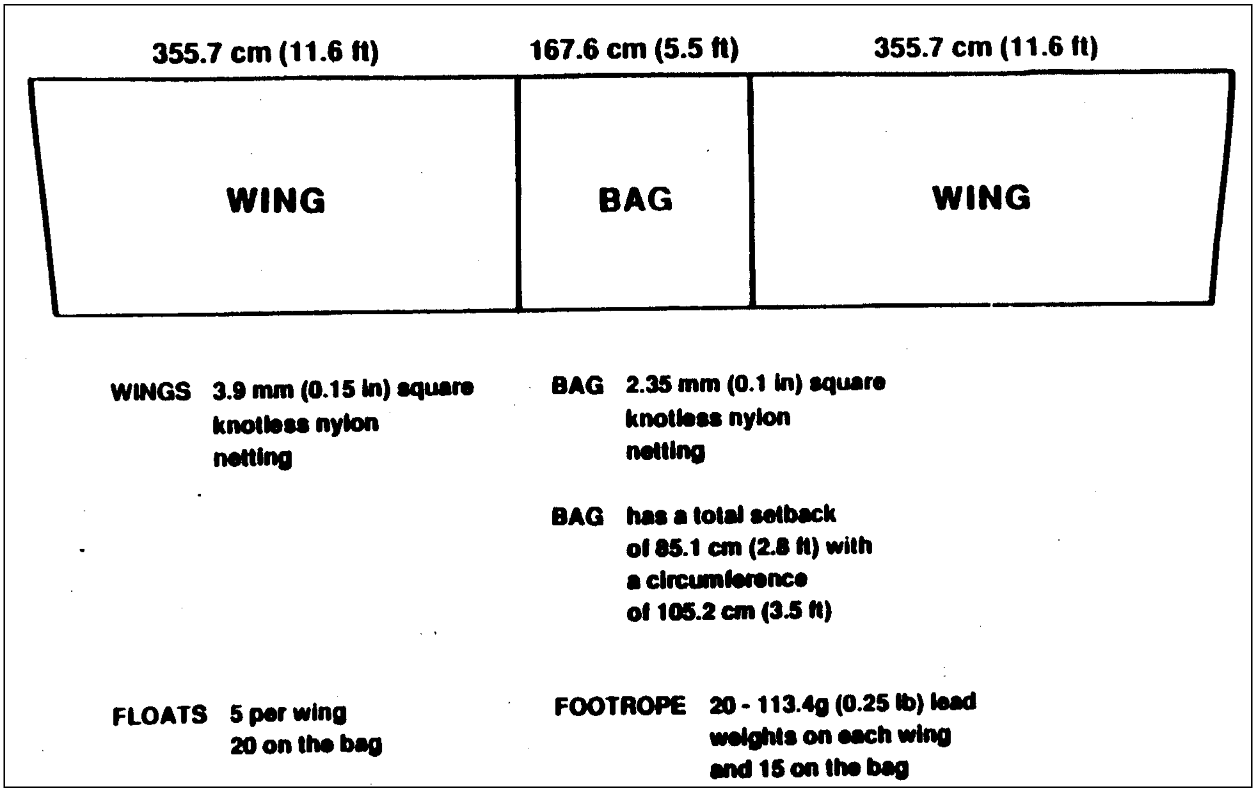


Figure B-2. Net plan for the 9-m beach seine.

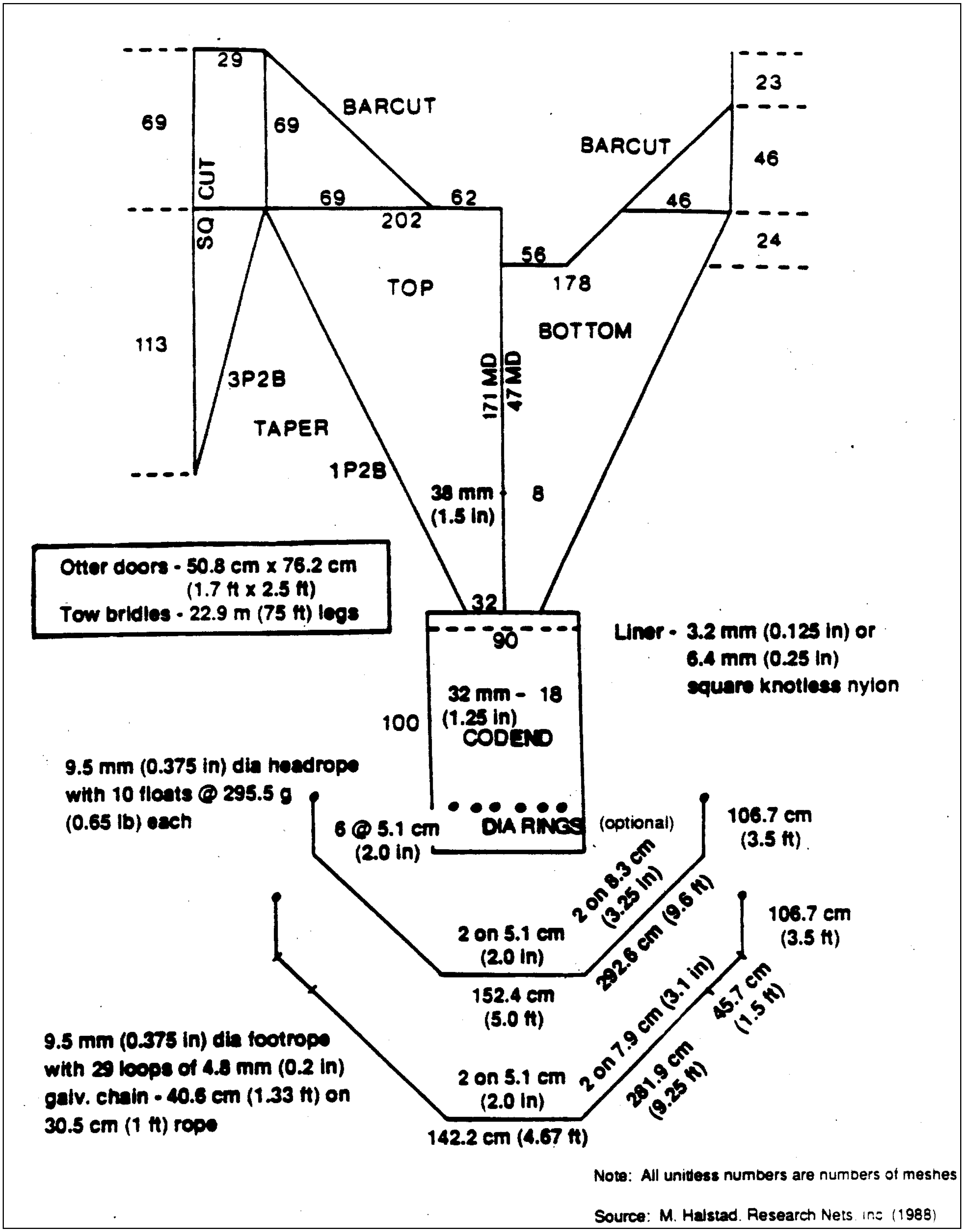
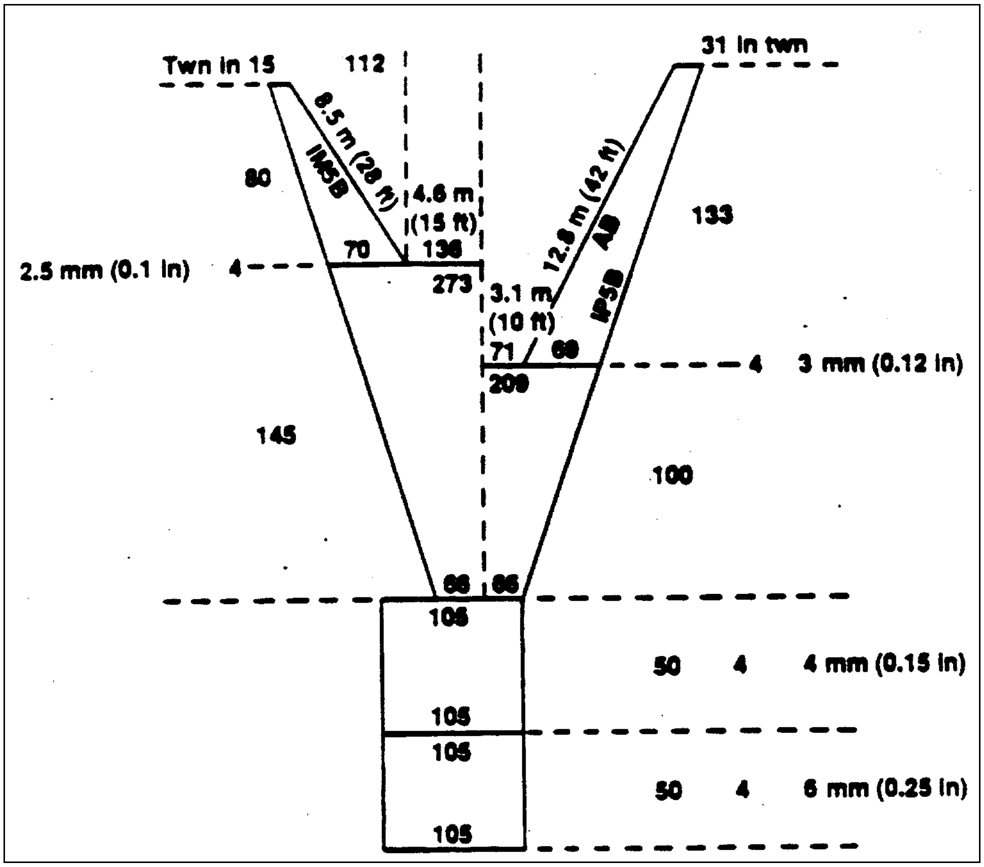


Figure B-3. Net plan for the 7.6-m otter trawl.



Note: All unitless numbers are numbers of meshes.

Figure B-4. Net plan for the 400-mesh eastern otter trawl.

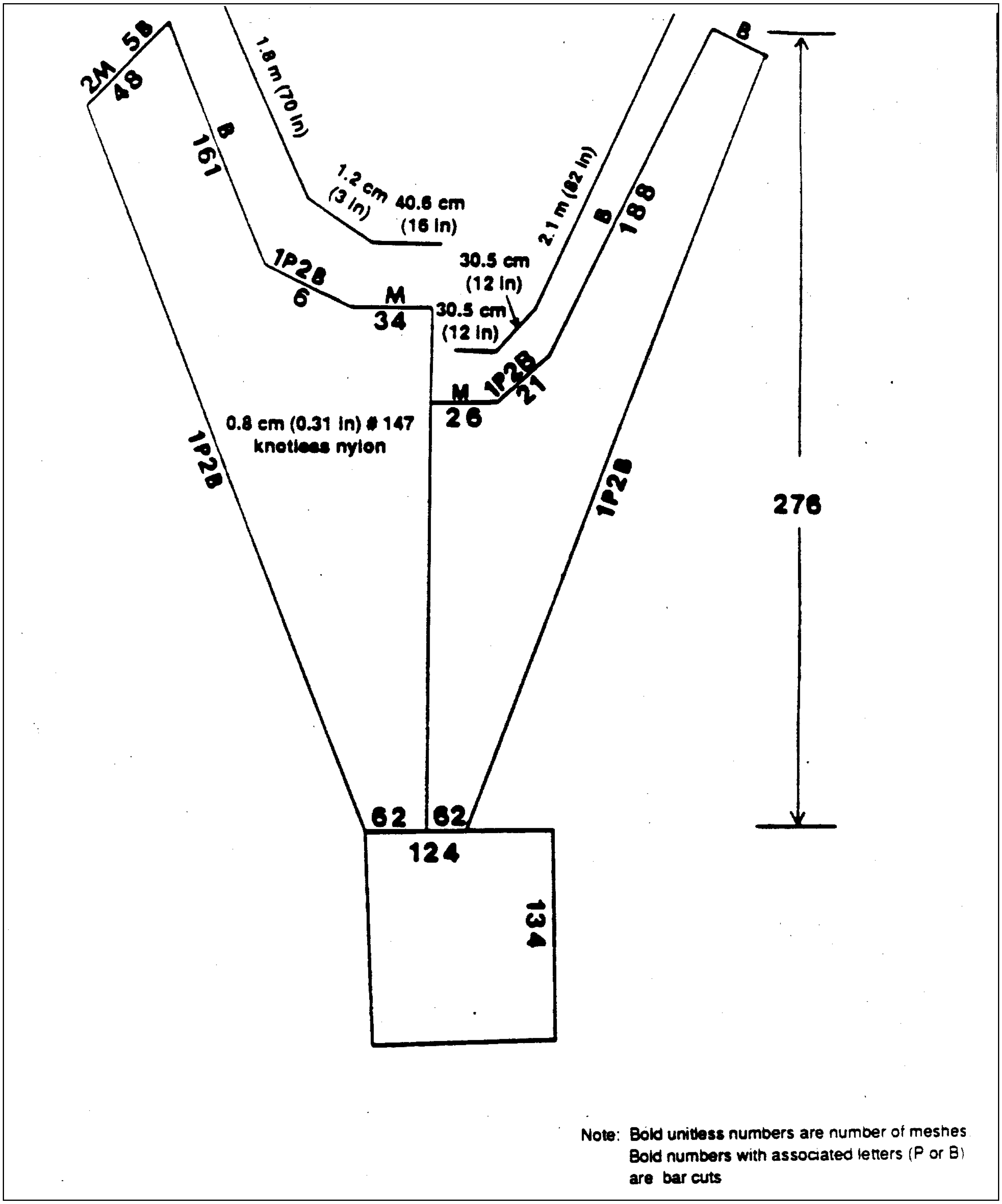


Figure B-5. Net plan for the 3-m beam trawl.

APPENDIX C

Additional Recommendations for Conducting Quantitative Sampling of Demersal Fishes in Puget Sound (Provided by Charles Eaton)

Additional Recommendations for Conducting Quantitative Sampling of Demersal Fishes in Puget Sound (Provided by Charles Eaton)

Accurate data on position, tow direction, and length of tow are needed to determine where samples are collected, to allow accurate repetitive sampling of stations, and to calculate the area of bottom sampled. Recent improvements of the quality of onboard electronics [including day-screen radar with built-in variable range markers (VRM), sophisticated loran systems with multiple navigation capabilities (e.g., Northstar 800), and video depth sounders and plotters] have dramatically increased the level of trawl quantification and repeatability. This appendix describes a set of methods that are currently in use in Puget Sound for conducting quantitative sampling of demersal fishes.

USE OF RADAR VARIABLE RANGE MARKERS

In areas where trawling is conducted towards or away from a reliable radar range (e.g., shore, dock, navigation marker), the VRM on the radar may be used to determine transect length. The distance to the object is noted as the winch is stopped and the vessel begins the tow by adjusting the VRM and reading off the distance. The designated length of the tow is then subtracted from this number. For example, with a tow distance of 0.20 nm, this amount is subtracted from the distance to the object at the beginning of the tow and the VRM ring is adjusted to this smaller size. As this smaller VRM ring touches the range, the winch is engaged to retrieve the trawl, ensuring the designated transect length is achieved.

USE OF LORAN POSITIONS, TIMES, AND WAYPOINTS

The loran-waypoint method of trawl quantification allows for transect measurement even in areas where convenient radar ranges are either absent or are so distant that they do not provide the needed accuracy. The ability to store and retrieve numerous data at the convenience of the operator also contributes to the accuracy of the tow during the often hectic environment of research trawl deployment and retrieval. A quality loran system (e.g., Northstar 800 or equivalent) is needed because of its ability to bring in signals in noisy radio environments, and because of its sophisticated navigation functions.

As the trawl is initiated, the time and ship's position can be stored in the loran by pressing the "save" button. This information can then be recalled at the convenience of the operator, and stored in the first of three data columns quantifying the station. Bottom depth and magnetic course are also entered in this first column labeled "Start Set." As the boat moves forward, the trawl is left behind in the water column, descending to the bottom while making very little forward progress. The data on position of the vessel in this first column therefore corresponds closely to the beginning of the area sampled. When the trawl warp has reached its designated towing length, the winch is stopped and the actual tow begins. Time and position are once again entered into the loran by pressing the "save" button. The time delays (TDs), latitude/longitude, and time (hour/min/sec) are then recorded in the second column of data labeled "Start Tow." Once again, the depth and magnetic course are also recorded.

The loran-waypoint navigation function is then used to determine the length of the tow. The operator enters the second saved position as a loran waypoint. The loran then reads out a bearing (magnetic or true course) and a constantly increasing range (distance) to the waypoint, which corresponds to the ship's position at the beginning of the tow. When the loran reads out the designated transect length, this third position is saved, after noting the distance and bearing (the reverse of the course of the vessel from the starting point). The winch is then engaged to terminate the tow and the information on vessel position is recorded in the third column of data labeled "End Tow."

The recorded data appears in the following three columns:

I. Start Set	II. Start Tow	III. End Tow
1. Depth	Depth	Depth
2. Loran TDs	Loran TDs	Loran TDs
3. Loran Latitude/Longitude	Loran Latitude/Longitude	Loran Latitude/Longitude
4. Loran Time	Loran Time	Loran Time
5. Radar Ranges and Bearings (optional)	Radar Ranges	Radar Ranges
6. Magnetic Course or Compass Course	Course	Loran Bearing to II
7. --	--	Tow Distance (Loran to II)
8. --	--	Tow Speed = $\frac{\text{Tow Distance}}{\text{loran time III - loran time II}} \times 60$

In the event of repetitive trawling at a given station, the loran TDs under column I can be entered into the loran as a waypoint to guide the vessel to the beginning of the transect. The magnetic course and the bottom contour on the video depth recorder or chart recorder can also guide the vessel for accurate transect repetition.

In order to plot the trawl station on a chart, the investigator can first plot the three positions as points along a line. The recorder would then draw a line originating at the first point, and averaging the positions of the remaining two points while maintaining a straight line. The trawl can be highlighted along this line at the designated distance starting at position I. As a check, the distance between points II and III should equal the distance of the tow as listed under column III.

To increase the accuracy of the plot, the loran's latitude and longitude can be corrected by entering a "bias" if the loran has been ground-truthed to known geodetic points for the area under investigation. This can be done by transporting the loran to known points, or by using microwave transponders to obtain known positions of the vessel within the study area which can be compared to the loran readouts for latitude and longitude. The bias can then be entered to give true latitude/longitude readings.

Transect lines can also be set up on the loran when towing video sleds, hydroacoustic gear, or physical oceanographic equipment. Waypoints at the beginning and end of the transect line are entered into the loran, which then gives constant information on range and bearing to the end of the transect plus vessel distance either right or left of the line.